



# Determining optimum harvest time for guayule latex and biomass

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## ABSTRACT

Guayule (*Parthenium argentatum* Gray) is a perennial shrub native to the Chihuahuan Desert of Northern Mexico and the Big Bend area of southwest Texas. One of the most valuable products from guayule is its hypoallergenic latex. However, little research has been done on the optimum harvest time for latex concentration and yield. The objective of this study was to determine the optimum harvest time during the growth cycle for latex content, plant biomass, and latex yield of guayule. Treatments consisted of three guayule lines (11591, AZ3, and G7-11TC) harvested every other month for 2 years. Plants were transplanted on 4 April 1995 at the University of Arizona Maricopa Agricultural Center, Maricopa, Arizona. Harvesting began in March 1998 and continued every other month through January 2000. Samples were analyzed for latex concentration and total biomass. Latex yields were calculated as the product of the latex concentration times the dry plant biomass. The experimental design was a randomized complete block with four replications. Results varied among lines and harvest dates. There appears to be enough differences among lines that planting lines selected for different optimum harvest dates would allow growers to spread the optimum harvest time throughout most of the year. This would also benefit processors by allowing them to reduce their production costs by spreading the harvest over several months instead of only a few months. More research must be done to determine whether specific environmental factors can be associated with the optimum harvest time and line specific harvesting guides such as growing degree days or other methods for determining optimum harvest date can be utilized in guayule.

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## 1. Introduction

Guayule (*Parthenium argentatum* Gray) is a perennial shrub native to the Chihuahuan Desert of Northern Mexico and the Big Bend area of southwest Texas (McGinnies and Mills, 1980). Two accomplishments have lead to the current efforts to commercialize guayule. First, the development and release of new germplasm has shortened the harvest time period from 3 to 5 years to 2 to 3 years (Estilai, 1985, 1986; Ray et al., 1999, 2005; Foster and Coffelt, 2005). Second, the finding that latex from guayule does not contain the allergy causing proteins found in Hevea (*Hevea brasiliensis* Willd., Muell.-Arg.) latex has made guayule latex an attractive source of hypoallergenic products for the medical industry (Siler and Cornish, 1994).

An important aspect of latex production is the timing of harvest of this perennial shrub to maximize latex yields. Previous reports indicate that rubber synthesis is seasonal and most active under cold temperatures (Hammond and Polhamus, 1965; Gilliland and Van Staden, 1986; Benedict et al., 1986; Appleton and Van Staden,

1991). However, past reports on optimum times to harvest solid rubber may not apply to latex rubber. Little research has been done on the optimum harvest time for latex concentration and yield. Only Coates et al. (2001) from a study in Argentina have reported on determining an optimum harvest date for latex. They found that results varied among the lines tested indicating season did not affect optimum harvest time for latex. Knowing when to harvest guayule for optimum latex yield in the USA has not been reported. Answering this question would enable growers and processors to schedule harvesting operations for maximum output and profit. The objective of this study was to determine the optimum harvest time during the growth cycle for latex content, plant biomass, and latex yield of guayule.

## 2. Materials and methods

The experiment was conducted at the University of Arizona Maricopa Agriculture Research Center in Maricopa, Arizona. Plants were transplanted to the field on 4 April 1995. The study was conducted for 2 years (March 1998 to January 2000). Three guayule lines were evaluated, including an older line (11591) as a check, a newly released line (AZ3) (Ray et al., 1999), and an unreleased breeding line (G7-11TC). The unreleased line G7-11TC is a selec-

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tion from AZ2 (Ray et al., 1999) that was initiated by tissue culture for the first planting after selection, but has been maintained by seed since the initial increase. The lines were chosen to represent both the older lines and newer germplasm in the breeding program. Lines were planted in a randomized complete block design with four replications. Two plants per line per replication were harvested every 2 months using the method of Coffelt and Nakayama (2007) from the time the plants were approximately 3 years old until they were over 4 years old. Samples were analyzed for latex concentration in the laboratory (Cornish et al., 1999) and latex yields were calculated based on the latex concentration and the dry plant biomass. Data were analyzed using analyses of variance (SAS, 1987). Means were separated using Duncan's New Multiple Range Test at the  $P=0.05$  level. Main effects were lines (fixed), years (random), harvest dates (fixed), and replications within harvest dates.

### 3. Results and discussion

Results showed significant differences among lines for latex concentration, biomass, and latex yield (Tables 1–3). Means over both years (March 1998 to January 2000) and all harvest dates showed AZ3 was significantly lower in latex concentration, G7-11TC was significantly lower in biomass, and 11591 was significantly higher in latex yield than the other two lines. Means over the three lines for all harvest dates showed latex concentration was significantly higher the first harvest year (March 1998 to January 1999), while biomass and latex yield were significantly higher the second harvest year (March 1999 to January 2000) of the study. The higher latex concentration in the first year was probably a function of the lower biomass for the first year.

Means over lines for the 12 harvest dates indicated that generally January of both years was the best month for harvesting for latex concentration and July 1999 was the worst month (Table 1). Results for plant biomass were more related to the year of harvest than a specific month with all harvest dates the second harvest year, except May and July, higher in biomass than all harvest dates the first harvest year, except March (Table 2). Results for harvest dates indicated that January 2000 or the last harvest was significantly higher than all other harvest dates for latex yield, while May 1998 produced the lowest latex yields (Table 3).

**Table 1**

Latex concentration (%) of three guayule lines harvested every 2 months from March 1998 to January 2000.

Harvest date	11591	AZ3	G7-11TC	Mean
March 1998	1.86 ab <sup>a</sup>	1.33 a	2.18 a	1.79 ab <sup>b</sup>
May 1998	1.20 b	1.34 a	1.56 ab	1.37 bcde
July 1998	1.92 a	1.15 a	1.61 ab	1.56 abcd
September 1998	1.95 a	1.50 a	1.77 ab	1.74 abc
November 1998	1.82 ab	1.00 a	1.41 b	1.41 bcde
January 1999	2.00 a	1.68 a	1.92 ab	1.87 a
March 1999	1.34 b	1.46 ab	2.00 a	1.60 abcd
May 1999	1.59 ab	0.92 b	1.66 ab	1.39 bcde
July 1999	1.23 b	0.84 b	0.97 b	1.01 e
September 1999	1.58 ab	0.86 b	1.32 b	1.25 de
November 1999	1.75 ab	1.24 ab	1.08 b	1.36 cde
January 2000	2.06 a	1.63 a	1.91 ab	1.87 a
Harvest year 1				1.62 A <sup>c</sup>
Harvest year 2				1.41 B
Line mean	1.69 A <sup>c</sup>	1.24 B	1.61 A	

<sup>a</sup> Means followed by the same letter within a line are not significantly different according to Duncan's Multiple Range Test ( $P=0.05$ ).

<sup>b</sup> Means over 3 lines for 12 harvest dates followed by the same letter are not significantly different according to Duncan's Multiple Range Test ( $P=0.05$ ).

<sup>c</sup> Means for years over all harvest dates and lines and means for lines over all harvest dates and harvest years followed by the same letter are not significantly different according to Duncan's Multiple Range Test ( $P=0.05$ ).

**Table 2**

Biomass (g/2 plants) of three guayule lines harvested every 2 months from March 1998 to January 2000.

Harvest date	11591	AZ3	G7-11TC	Mean
March 1998	1216 a <sup>a</sup>	856 a	769 a	947 ab <sup>b</sup>
May 1998	590 a	646 a	481 b	572 b
July 1998	726 a	514 a	444 b	561 b
September 1998	852 a	749 a	366 b	656 b
November 1998	1022 a	853 a	590 ab	822 b
January 1999	924 a	800 a	639 ab	788 b
March 1999	1180 a	948 a	1049 a	1059 ab
May 1999	1012 a	942 a	635 ab	863 b
July 1999	1461 a	585 a	541 b	862 b
September 1999	1078 a	1291 a	633 ab	1001 ab
November 1999	1371 a	1849 a	565 b	1262 a
January 2000	1259 a	1904 a	673 ab	1278 a
Harvest year 1				724 B <sup>c</sup>
Harvest year 2				1054 A
Line mean	1057 A <sup>c</sup>	993 A	616 B	

<sup>a</sup> Means followed by the same letter within a line are not significantly different according to Duncan's Multiple Range Test ( $P=0.05$ ).

<sup>b</sup> Means over 3 lines for 12 harvest dates followed by the same letter are not significantly different according to Duncan's Multiple Range Test ( $P=0.05$ ).

<sup>c</sup> Means for years over all harvest dates and lines and means for lines over all harvest dates and harvest years followed by the same letter are not significantly different according to Duncan's Multiple Range Test ( $P=0.05$ ).

The line  $\times$  harvest date interaction was significant for the three traits studied. Optimum harvest dates for latex concentration in 11591 occurred in the January 1999, September 1998, and July 1998 of the first harvest year and January 2000 of the second harvest year (Table 1). All harvest dates the first harvest year (March 1998 to January 1999) for AZ3 and January 2000 of the second harvest year were significantly higher in latex concentration than May 1999, July 1999, and September 1999 harvest dates of the second harvest year. Optimum harvest date for latex concentration in G7-11TC was March of both harvest years (1998, 1999), while the November harvest date in both harvest years (1998, 1999) and July 1999 and September 1999 harvest dates the second harvest year were significantly lower. Biomass was not significantly different for any of the harvest dates of 11591 or AZ3, while biomass of G7-11TC was significantly higher for the March (1998, 1999) harvest dates

**Table 3**

Latex yield (g/2 plants) of three guayule lines harvested every 2 months from March 1998 to January 2000.

Harvest date	11591	AZ3	G7-11TC	Mean
March 1998	21.7 a <sup>a</sup>	11.7 a	17.1 a	16.8 b <sup>b</sup>
May 1998	7.3 b	8.8 a	6.3 b	7.5 c
July 1998	13.9 ab	6.2 a	7.1 b	9.1 bc
September 1998	16.6 ab	10.9 a	7.6 b	11.7 bc
November 1998	18.1 ab	13.2 a	9.4 b	13.6 bc
January 1999	18.6 ab	13.4 a	12.2 ab	14.7 bc
March 1999	20.7 a	15.6 abc	10.1 b	15.5 bc
May 1999	15.9 a	8.3 bc	6.0 b	10.1 bc
July 1999	17.8 a	3.7 c	6.2 b	9.2 bc
September 1999	18.0 a	10.7 bc	8.3 b	12.3 bc
November 1999	25.7 a	19.1 ab	10.1 b	18.3 b
January 2000	26.7 a	28.6 a	18.5 a	24.6 a
Harvest year 1				12.2 B <sup>c</sup>
Harvest year 2				15.0 A
Line mean	18.4 A <sup>c</sup>	12.5 B	9.9 B	

<sup>a</sup> Means followed by the same letter within a line are not significantly different according to Duncan's Multiple Range Test ( $P=0.05$ ).

<sup>b</sup> Means over 3 lines for 12 harvest dates followed by the same letter are not significantly different according to Duncan's Multiple Range Test ( $P=0.05$ ).

<sup>c</sup> Means for years over all harvest dates and lines and means for lines over all harvest dates and harvest years followed by the same letter are not significantly different according to Duncan's Multiple Range Test ( $P=0.05$ ).

(Table 2). Latex yields were significantly higher for the harvest dates in the second harvest year (March 1999 to January 2000) and March 1998 of the first harvest year than the May 1998 harvest date the first harvest year for 11591 (Table 3). Latex yields for AZ 3 were significantly higher for all harvest dates the first harvest year (March 1998 to January 1999) and the January 2000 harvest date the second harvest year than the May 1999, July 1999, and September 1999 harvest dates the second harvest year. Latex yields on the March 1998 harvest the first harvest year and January 2000 harvest the second harvest year were significantly higher than all other harvest dates, except the January 1999 harvest date the first harvest year for G7-11TC.

Based on previous reports on the time when rubber synthesis occurs in guayule (Hammond and Polhamus, 1965; Gilliland and Van Staden, 1986; Benedict et al., 1986; Appleton and Van Staden, 1991), one would expect maximum latex concentration to occur in the spring harvests (March to May). Results from this study (Table 1) indicate that while this may be partially correct high latex concentrations were also found at other times of the year depending upon the line and harvest date. The only consistently low latex concentration across all lines occurred in July the second harvest year. In contrast to latex concentration, one would expect maximum biomass to occur in the fall (September to November) following plant growth during the summer. We did not observe a significant increase in biomass within lines at the September and November harvests compared to the two harvests immediately preceding them (Table 2). When results were combined across lines, harvests from September to March produced more biomass than harvests in May and July and plants harvested the second harvest year were larger than those harvested the first harvest year. Latex yield for 11591 appeared to be affected more by latex concentration the first harvest year and plant biomass the second harvest year (Table 3), while latex yield for AZ3 appeared to be influenced most by latex concentration the second harvest year. Latex concentration of G7-11TC appeared to be equally influenced by both latex concentration and biomass.

Comparison of biomass results for AZ3 and 11591 in this study with two recent studies (Coffelt et al., 2009; Dissanayake et al., 2007) support conclusions from previous studies (Coffelt et al., 2005; Dierig et al., 2001) that environment can play an important role in evaluating guayule lines. AZ-3 was significantly higher in biomass than 11591 in one study (Coffelt et al., 2009), but not in this study or one conducted in Australia (Dissanayake et al., 2007). It is also important to remember that guayule lines are really populations and not pure lines and not as uniform from plant to plant as with most commercial crops (Ray et al., 2005).

Results from this study generally agree with those reported by Coates et al. (2001) in a study conducted in Argentina. There appears to be enough differences among lines that planting lines selected for different optimum harvest dates would allow growers to spread the optimum harvest time throughout most of the year. This would also benefit processors by allowing them to reduce their production costs by spreading the harvest over several months

instead of only a few months (Coates et al., 2001). More research must be done to determine whether specific environmental factors can be associated with the optimum harvest time and line specific harvesting guides such as growing degree days or other methods for determining optimum harvest date can be utilized in guayule.

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## References

- Appleton, M.R., Van Staden, J., 1991. Influence of temperature and daylength on growth and isoprenoid biosynthesis in guayule under controlled environmental conditions. *Bioresour. Technol.* 35, 147–152.
- Benedict, C.R., Rosenfield, C.L., Gale, M.A., Foster, M.A., 1986. The biochemistry and physiology of isopentenyl pyrophosphate incorporation into cis-polyisoprene in guayule plants. In: Benedict, C.R. (Ed.), *Biochemistry and Regulation of Cis-polyisoprene in Plants*. Texas A&M Univ., College Station, TX.
- Coates, W., Ayerza, R., Ravetta, D., 2001. Guayule rubber and latex content—seasonal variations over time in Argentina. *Ind. Crops Prod.* 14, 85–91.
- Coffelt, T.A., Ray, D.T., Nakayama, F.S., Dierig, D.A., 2005. Genotype and environmental effects on guayule (*Parthenium argentatum*) latex and growth. *Ind. Crops Prod.* 22, 95–99.
- Coffelt, T.A., Nakayama, F.S., 2007. A six step harvesting procedure for guayule small plots for laboratory analyses. In: Janick, J., Whipkey, A. (Eds.), *Issues in New Crops and New Uses*. ASHS Press, Alexandria, VA, pp. 66–71.
- Coffelt, T.A., Nakayama, F.S., Ray, D.T., Cornish, K., McMahan, C.M., Williams, C.F., 2009. Plant population, planting date, and germplasm effects on guayule latex, rubber, and resin yields. *Ind. Crops Prod.* 29, 255–260.
- Cornish, K., Chapman, M.H., Nakayama, F.S., Vinyard, S.H., Whitehand, L.C., 1999. Latex quantification in guayule shrub and homogenate. *Ind. Crops Prod.* 10, 121–136.
- Dierig, D.A., Ray, D.T., Coffelt, T.A., Nakayama, F.S., Leake, G.S., Lorenz, G., 2001. Heritability of height, width, resin, rubber, and latex in guayule (*Parthenium argentatum*). *Ind. Crops Prod.* 13, 229–238.
- Dissanayake, P., George, D.L., Gupta, M.L., 2007. Improved guayule lines outperform old lines in south-east Queensland. *Ind. Crops Prod.* 25, 178–189.
- Estilai, A., 1985. Registration of CAL-5 guayule germplasm. *Crop Sci.* 25, 369–370.
- Estilai, A., 1986. Registration of CAL-6 and CAL-7 guayule germplasm. *Crop Sci.* 26, 1261–1262.
- Foster, M.A., Coffelt, T.A., 2005. Guayule agronomics: establishment, irrigated production, and weed control. *Ind. Crops Prod.* 22, 27–40.
- Gilliland, M.G., Van Staden, J., 1986. Cyclic patterns of growth and rubber deposition in guayule *Parthenium argentatum*. Suggestions for a management programme. *S. Afr. J. Plant Soil* 3, 21–26.
- Hammond, B.L., Polhamus, L.G., 1965. Research on Guayule (*Parthenium argentatum*): 1942–1959. USDA Technical Bulletin. U.S. GPO, Washington, DC, 157 pp.
- McGinnies, W.G., Mills, J.L., 1980. Guayule Rubber Production: The World War II Emergency Rubber Project. Office of Arid Lands Studies, University of Arizona, Tucson, AZ.
- Ray, D.T., Dierig, D.A., Thompson, A.E., Coffelt, T.A., 1999. Registration of six guayule germplasms with high yielding ability. *Crop Sci.* 39, 300.
- Ray, D.T., Coffelt, T.A., Dierig, D.A., 2005. Breeding guayule for commercial production. *Ind. Crops Prod.* 22, 15–25.
- Institute, S.A.S., 1987. The GLM procedure. In: *SAS/STAT Guide for Personal Computers* Version 6 Ed. SAS Institute, Inc., Cary, NC, pp. 549–640.
- Siler, D.J., Cornish, K., 1994. Hypoallergenicity of guayule rubber particle proteins compared to Hevea latex proteins. *Ind. Crops Prod.* 2, 307–313.